THE EXPERIMENT OF APPLYING PLASMA CHEMICAL REACTION AND NON—PLASMA CHEMICAL REACTION IN THE R.F. ION SOURCE

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Abstract

The application of the plasma chemical reaction in the R.F.ion source,the difference between the metal ion extracted from the R.F.ion source by applying plasma chemical reaction and by non-plasma chemical reaction, that had been reported.(I)(2) This paper is recount an experiment device,it is utilized to create a condition,in order to the denudation rate of the plasma to metals can compare with non-plasma,remove the error by condition change which is not seen easily in different time experiment,also avoid the differece by experimenter is accustomed to oprate.The experiment provided according to select the structure of the metal ion extracted by applying plasma chemical reaction in the R.F.ion source.

I. The exparimental structure and working principle.

For comparing the difference of the plasma chemical reaction and non-plasma chemical reaction,condition of comparing them must be created, the structure used in this experiment is shown in fig.I. Fig. I-1,I-2,I-3,I-4, I-5 are four tungsten sticks (there are five parts),they are cuted from a tungsten pole with same diameter, they are all put into a discharge chamber. I-I is exposed in the plasma, and is at a negative potential. I-2 and I-I are a pole,at a negative potential too,but it is shielded by a quartz glass tube with an internal diameter ϕ 4mm. I-3 is shielded by a quartz glass tube with an internal diameter ϕ 4mm, and freely set in the plasma region, it is not directly exposed in the plasma. I-4 is directly exposed in the plasma. I-5 is at a positive potential, it is not shielded too.

After the halogen family element (or the halide) enter the discharge chamber,it is ionized by a high frequency electromagnetic field, and plasma is formed.chemical reaction is caused in it with five metals pole at the same time. The reaction is go on at certain entering gas quantity and under a same discharge power condition with the same time of beginning and ending.

2. The experimental results

2.I the comparision of the results of chemical reaction for the five metal poles with the halogen.

The changing rate of the diameter of the metal poles is measured in experiment for many time and the variation of them is different.the changing rate of diameter is the reduction quantity of the metal pole in diameter after the chemical reaction of the metal pole with the halogen during a definite time.The rate of I-3 is the least,it is used as a criterion for the datum, with which the rate of others is compared. Because I-2 and I-3 are in a roughly similar condition,their change are identical. I-4 is four to six time as large as I-3. I-5 is six to ten time as large as I-3. I-I is 3 more orders of magnitude than I-3.

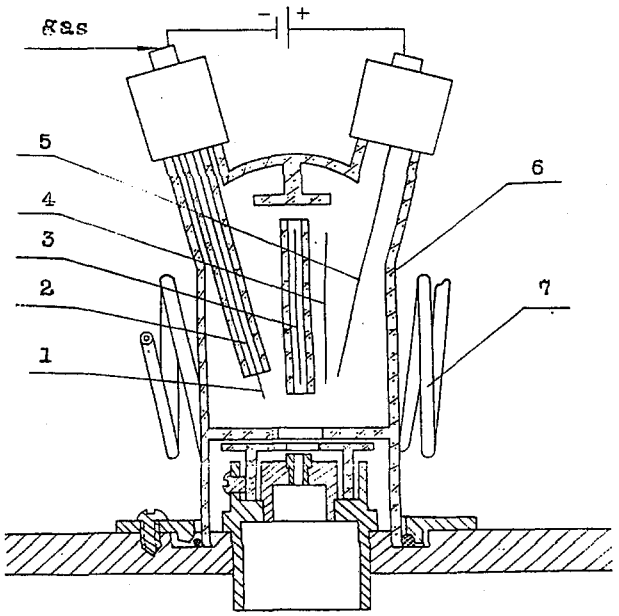

Fig.I ·The structure for processing plasma chemical reaction and non-plasma chemical reaction in the R.F.ion source.

(I)(2)(3)(4)(5)are tungsten poles; (6)the discharge chamber made of quartz glass; (7)the coil of the R.F. oscillator.

2.2 The case of extracting metal ion by the use of the structure I-3 and I-4 respectively.

(I)The experimental results of using structure I-3 is showed in fig.2 and fig.3.

(2) The experimental results of applying structure I-4 is shown in fig.4, fig.5 and fig.6.

one can see from experimental results in both case that when the plasma chemical reaction is applied, usefull metal ion content proportion is higher in the ion beem than that of non-plasma range chemical reaction. When form I-3 is used, p^{d+} smaller than IO% in total ion beem, Ag^{+} makes up only 6% and Ta^{+} can not see in ion mass spectrum .whereas when form I-4 is used, A_g^{+} maked up 40%, Ta^{+} makes up 67% and W^{+} makes up 30%.

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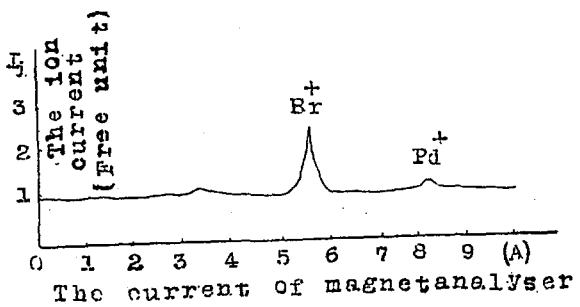


Fig. 2 The ion mass spectrum of $^{pd} + BB_{r3}$ by using structure I-3.

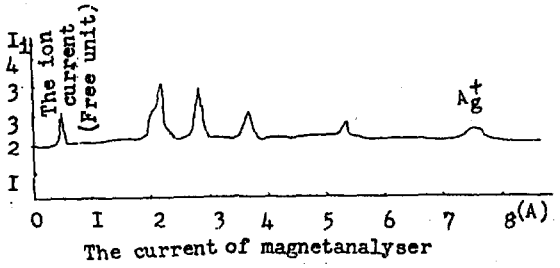


Fig.3 The ion mass spectrum of $A_g + BF_3$ by using structure I-3.

3. Discussion

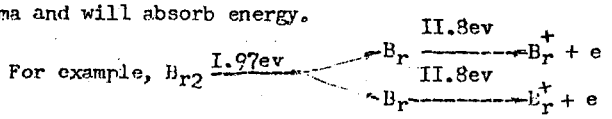
The experimental results has showed that the etching rate of the metal exposed in plasma is higher than in quartz tube, therefor wanted the metal ion content proportion higher in ion beam. the reason is that ionizetion rate is higher in plasma than in quartz glass tube (or non-plasma range) and there are many favourable factors present, specially more high energy particles and activeted particles.

3.I The comparison of I-4 and I-3.

(I) I-4 form there is more electrons than I-3, the electrons which constitute about one half of the amount of charged particles possess higher energy by I to 2 orders of magnitude(3)(4)than the molecules, the atoms and the particles in glass tube in the same plasma. The electrons in plasma are the most active ones in all particles. The energy increase in the discharge chamber is essentially transfered by electrons which make the molecules resolved, the atoms and the molecules etc. activated and ionized.

(2) The condition of I-4 is possessed of more activated particles than I-3.

The gas molecules of the halogen family elements are resolved easily into atoms in the process of their collision with particles (or bombarded by particles) in plasma and will absorb energy.



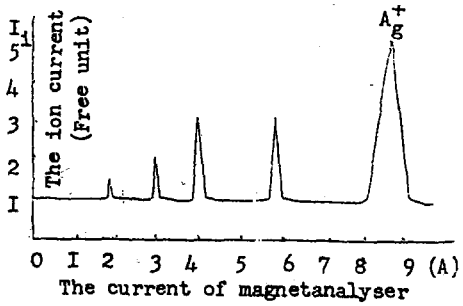


Fig.4 The ion mass spectrum of $A_{g+} BF_3$ by using structure I-4.

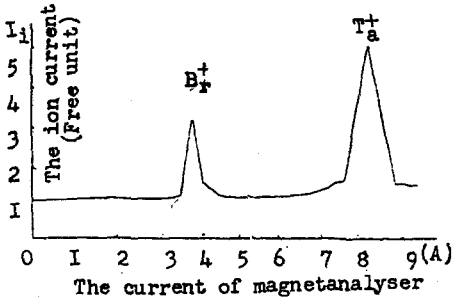


Fig.5 The ion mass spectrum of $T_a + BB_{r3}$ by using structure I-4.

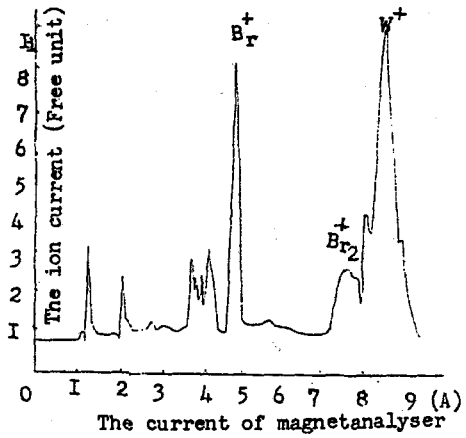
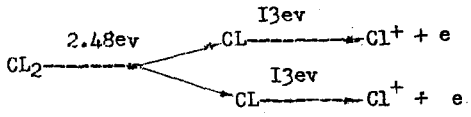


Fig.6 The ion mass spectrum of $W + BB_{r3}$ by using structure I-4.



For two Bromine atoms the energy increases I.97 ev which is more than that for one molecule (B_{r_2}). when a Bromine atom is ionized into an ion (B_r^+) and an electron (e)(a pair of ion and electron) the energy is increased by II.8ev, while two atoms (be a molecule) are ionized into two ions and two electrons, the energy are increased by 23.6ev + I.97ev = 25.57ev.

For two chlorine atoms the energy increases 2.48 ev which is more than that for one molecule (Cl_2). When a molecule (CL_2) is ionized into two ions and two elec-

trons (two pair of ion and electron),the energy are increased by 28.48ev.

The chemical activety of atoms is more intensive than that of molecules and is liable to cause chemical reaction.

The fact that ions join chemical reaction is a important charecteristic of the plasma chemical reaction. The ability of the ion acquiring electron are stronger than that of molecule and atom, so it is more easily to take place for the chemical reaction with the metal.

(3) there are much atoms (or molecules) in excited state in I-4 than in I-3 in discharge chamber. The excited atoms (or molecules) also possess more energy than the non excited ones.

such as, T_a^*(excited state)$_{2.6ev}$ energy more than T_a.

p^{d*}(excited state)$_{3.44ev}$ energy more than p^d .

One can know that great quantity of the excited state particles are present by the plasma light. For the excited particles the chemical reaction is easily to take place than the non excited ones.

(4) I-4 more the duo-pole diffusion effect(5) than I-3, that is an inherent physical characteristic at the boundary between the plasma and the suspension metel. Owing to this nature,(I) an amount of the halogen contact with the metal is increased; (2) particles flowing to the surface of the metal from the plasma have definite energy which causes the physical and chemical sputtering at the surface of the metal. This is a factor of the fact that the plasma range chemical reaction is faster than in the non-plasma range.

The duo-pole diffusion effect has bring into profitable play in the prossess of extracting metal ions from R.F.ion source when the plasma chemical reaction is applied.

Above mentioned factors and other beneficial factors existed in the plasma make the diameter changing rate of I-4 be 4 to 6 time as large as I-3, and make structure I-4 the extracted metal ion percentage in ion beam higher than form I-3.

3.2 I-5 is seted at positive potential,besides it and I-3 same occur chemical reaction with the neutral particles, it is impacted by many high energy electrons and negative ions, the contact quantity between the metal with the halogen is increased, but sputter, made corrode rate raise, so the change rate of I-5 is six to ten time as large as I-3.

3.3 I-I compare with I-3, to utilized advantageous condition in plasma more full, several thousand voltage difference is added between the I-5 (positive electrode) and the I-I (negative electrode) by outer power supply at the discharge chamber.Many positive ions of the halogen are forced to shoot towards I-I, the contact number of the halogen element particles with the metal much more increased.When the high energe particles bombard metals,the chemical reaction occures rapidly and the physical and chemical sputtering are more obvious. Therefore, the diameter changing rate of I-I is 3 more orders of magnitude than I-3, i.e. the diameter changing rate of I-I is 3 more orders of magnitude than I-2, but I-I and 1-2 is at the same tungsten pole, only the 1-2 is shielded by quartz glass tube. This explains that the conductance is no good in quartz glass tube, in other words, the ionizing rate is low. Although I-I and I-2 is at the same pole and at the same negative potential, the result have authentically 3 order difference of magnitudes.

4. The selection of the structure in practice

4.I I-4 form is used for some metals, because they are not need that are heated and impacted by particles in addition, only metal is put in plasma of the halogen, the chemical reaction can cause rapid, and the metal ion is extracted from ion source. For example, A_g, C_u, V, B_e and so on.

4.2 I-1 structure is used to high melting point metals, which is bombarded by ions, many metals ion are extracted from ion source. Such as, Y, T_a, C_r, $T_i$and so on. In order to raise percent of useful ion in beam, using a kind of the metal at I-I and I-5 at same time.

4.3 Low melting point metals, for instance, I_n, B_i, $G_a$and so on,they are put into crucible in discharge chamber to prevent flow.

The techniques of the plasma chemical reaction and the sputtering adopted in R.F. ion source are very effective for extracting the high melting point metal ions. The ions have been extracted are : R_e^+, W^+, Mo^+, T_a^+, A_u^+, P_t^+, A_g^+, p^{d+}, C_r^+, T_i^+, V^+, F_e^+, C_u^+, Al^+, S_i^+, B_e^+, B_i^+, I_n^+, G_a^+, L_i^+ and rare earth element ions Y^+, N_d^+, C_e^+ and so on.

This two techniques had been applying in 400kev ion implanter at Beijing Normal University.

5. Concluding remarks

The fact of expeiment further proved that the application of the plasma chemical reaction and the sputtering in R.F. ion source has its own merit, since for the R.F. ion source the quartz glass discharge chamber is used, while the chemical property of the quartz glass is more stable than that of metals and the metals that is no need to produce ion can be shielded,then the useful metals ion content is higher in the drawn ion beam. This method is simplicity and convenience. The noble metals can be economically used. This technology can be used at equipments with the R.F. ion source simply some

improvements are being made. The technology can be used to conduct mass spectrum analysis for certain plasma polymer.

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